Challenges Facing Puget Sound and Georgia Basin Scientists: Invited Presentations and Panel Discussion

Nancy McKay, Chair, Puget Sound Water Quality Action Team: It is my great pleasure to welcome you to Puget Sound Research 2001. This is the fifth in a series of conferences that we have sponsored to explore new science, new directions and new ideas for protecting the health of Puget Sound and the Georgia Basin. This conference is one means by which the Action Team seeks to reach a key goal of the *Puget Sound Water Quality Management Plan*, which is to fund and disseminate research that adds to the knowledge of the physical and biological systems of Puget Sound, that identifies causes and solutions of pollution problems, and that assists decision making activities of regulatory and management agencies while stimulating creativity and excellence in research.

To appropriately characterize Puget Sound and human interactions with the ecosystem, we require a great diversity of scientific information. The studies presented at the conference will improve the scientific basis for future decisions about how we can better protect and restore the Sound and the Georgia Basin. This conference on research is also an adjunct to the Puget Sound Ambient Monitoring Program, which is coordinated by the Action Team. The monitoring program collects, assesses and communicates information from a broad array of scientific disciplines—utilizing the expertise of multiple state and federal agencies, local governments and citizen monitoring programs. The program focuses on key conditions and trends in Puget Sound, including water and sediment quality, contamination and its effects on fish, bird and harbor seal abundance and the condition of our nearshore habitat. And you'll be hearing a lot about those topics during this conference.

We begin this day with a session that models the intent of our Research Conference, which is to give the region's scientists an opportunity to share their findings with their colleagues, resource managers and interested citizens. During this session we hope to initiate a conversation about challenging scientific problems and issues, which will continue throughout the conference and into the future. We also hope to challenge ourselves to take specific actions. Thus we use the word challenge in two ways, as a noun: a critical job task or problem. And a verb: to summon to action.

In this session three scientists will give a presentation on research that they have been doing. While you listen to their presentations we encourage you, if you wish to write down one question that you would like to address to one of the speakers. In the second half of this session, we will ask three more panelists to join us, and we will use your questions to begin a conversation among the entire panel.

This morning's presenters have been asked to speak for 20 minutes, which means that they are barely going to be able to talk to you about all of the research that they have been doing. They are going to have to condense a lot into a short period of time. All of them are well known scientists who have spent years doing research on key challenges facing Puget Sound and the Georgia Basin and all are also people who care mightily about the future of the Sound, the Basin and their resources.

There Goes the Rug

Dr. Philip Mote
Climate Impacts Group
University of Washington

I've entitled my talk, "There goes the Rug" because as we look to the future of the climate of the world and specifically the Northwest, we see the potential for the rug to be pulled out from under biological scientists. To begin with I want to describe some of the past climate variations that we've seen in the Pacific Northwest and how they affect ecosystems in the Puget Sound area. Next I want to describe the science of global climate change to try to cut through some of the confusion that the media sometimes puts on the issue and, finally, talk about climate change here.

I'm part of the Climate Impacts Group at the University of Washington, which is a really wonderful interdisciplinary team of scientist from several different backgrounds; we even include some economists and public policy types, which some of us in the physical scientists have difficulty talking to because we use very different language. But it's been a very enriching experience for all of us.

Our goal really is beyond science. It is to help the region become more resilient to climate variations and change, and in order to do that we have to plug into the policy process at various places.

To begin with, let's look at what external influences play a role in the climate of the Northwest. What's shown here (Figure 1) are two of those features of Pacific Ocean climate variability. On the right is the familiar El Niño Southern Oscillation, or ENSO, and what is shown are maps of sea surface temperature anomalies in degrees Celsius during a warm or El Niño event. The red patch shows unusually warm water along the central and eastern equatorial Pacific; the blue patch in the North Pacific is another key feature, but it is really a response to the tropical ENSO condition. There is also warm water along the west coast of both North and South America during a warm El Niño event.

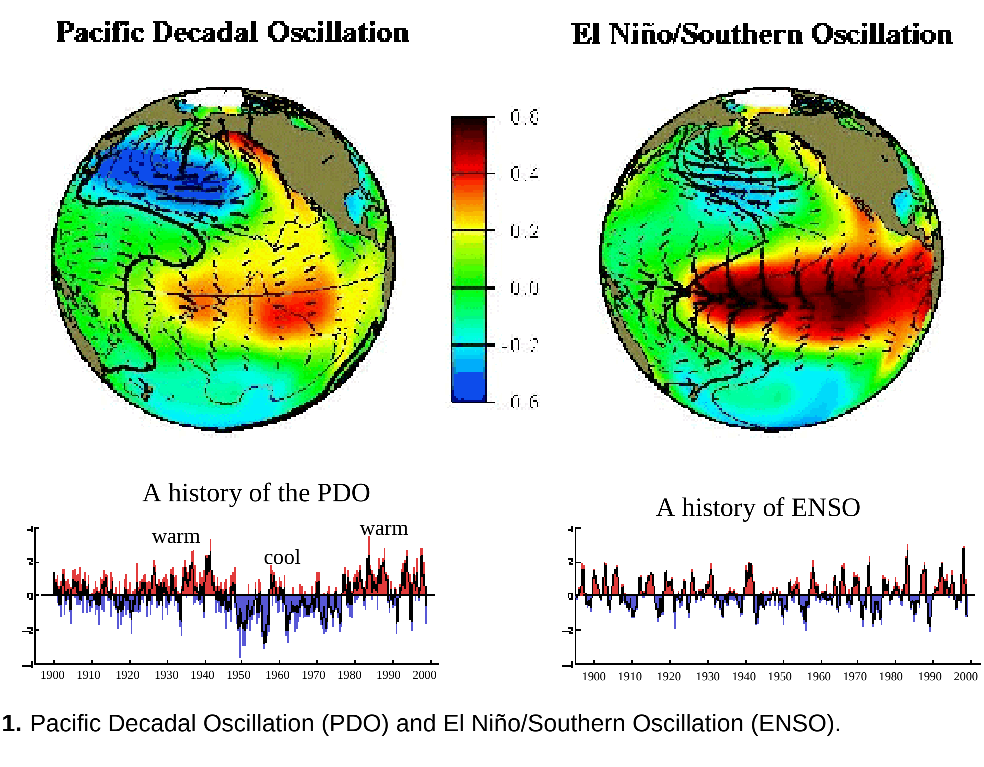

Figure 1. Pacific Decadal Oscillation (PDO) and El Niño/Southern Oscillation (ENSO).

Looking at the time history of ENSO, we see that it goes back and forth with a repeat period of somewhere between two and seven years. And the 1990s finished out with a couple of La Niña years. The early 90s had a string of El Niño years. On the left is a less familiar climate variation, known as the Pacific Decadal Oscillation, which was initially described by scientists in our group and represents one of the major triumphs of our research because of the link between the PDO and salmon.

The characteristic pattern of PDO is a cool patch of water in the North Pacific and warm on the coast. And you can see there are a lot of similarities between these sea surface temperature patterns in the warm phase. But the characteristic difference in the time history of the PDO tends to show a lot of persistence 20 to 30 years at a time in a warm phase or a cool phase. The late 1990s finished out with a few years with the PDO in cool conditions leading to the speculation that perhaps we could be heading into another prolonged cool phase, but we won't know that for another few years, unfortunately.

Well, to focus on the climate of Puget Sound, I'm using climate division data from the National Climate Data Center, and Climate Division 3 here simply groups stations in the Puget Sound area, and this next figure (Figure 2) shows how the temperature in those stations varies month by month according to El Niño or La Niña conditions. El Niño or warm ENSO years tend to be about one degree warmer in January, February and March tailing off into spring. La Niña or cool years tend to be a little bit cooler than average, but not quite as much as El Niño years.

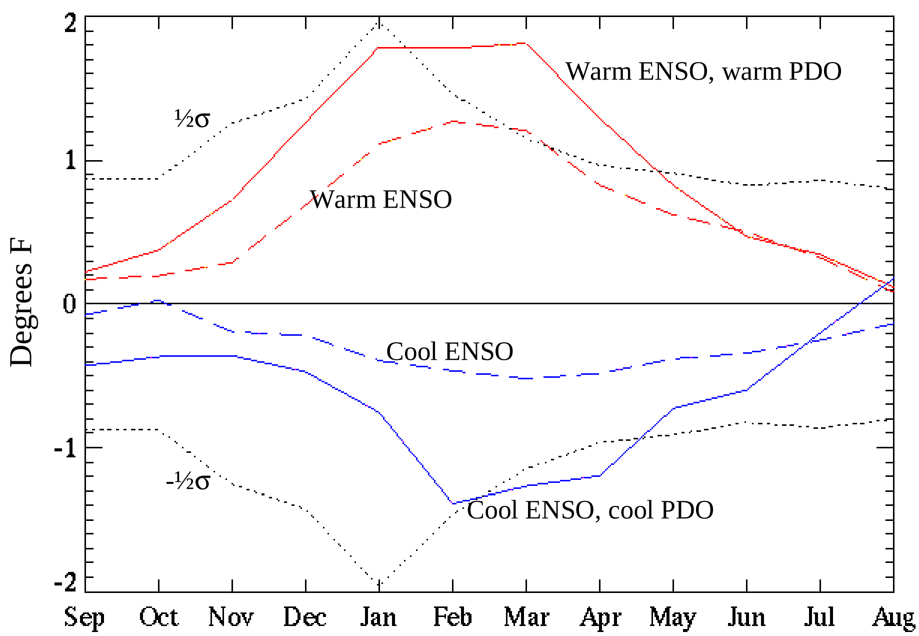

Figure 2. Effects of PDF and ENSO on Puget Sound area temperature.

If we also consider years when the PDO was in a warm phase, we see a sort of additive effect where the two tend to reinforce each other. And so warm years that are both warm ENSO and warm PDO tend to be roughly double and likewise cool ENSO and cool PDO. I've shown also here one half the standard deviation of the inter-annual time series of each month's temperature to give you an idea of what fraction of the variance corresponds with these two climate variations in the Pacific Ocean.

This shows the same plot for precipitation. I've now shifted back a month to show September on the left because there is really quite a large variation in precipitation in October and again plus and minus half a standard deviation. So cool ENSO and cool PDO conditions tend to correspond with wetter than average winters, and again the effect is roughly half a standard deviation in the most extreme months, which in this case are November, December and January, which as everyone who has lived here knows that's our wet, gray period anyway.

Looking at how these climate variations affect stream flow …this is the Cedar River (Figure 3) at the inflow to Chester Morse Reservoir from which City of Seattle gets a good deal of its water supply, and I would add also a lot of the suburbs. Bellevue and Redmond for example. And the cool ENSO conditions are shown here as a dashed curve. The winter stream flow tends to be a little higher because of higher rainfall. Part of this basin lies below snowline, so additional precipitation runs in as rainfall. And then there is another peak in spring when additional precipitation runs off as snow melt. And so, overall, the annual mean in La Niña years is 25% higher than in El Niño years. When you combine ENSO and PDO, you see again a sort of multiplying effect. The annual mean is about 50% higher when they are both in cool phase than when they are both in warm phase. So you can imagine that this sort of climate variation is very important for both urban water supply issues and also for ecosystems that thrive in the streams and indeed also Puget Sound, because the fresh water runoff into Puget Sound is clearly also driven by these two cycles.

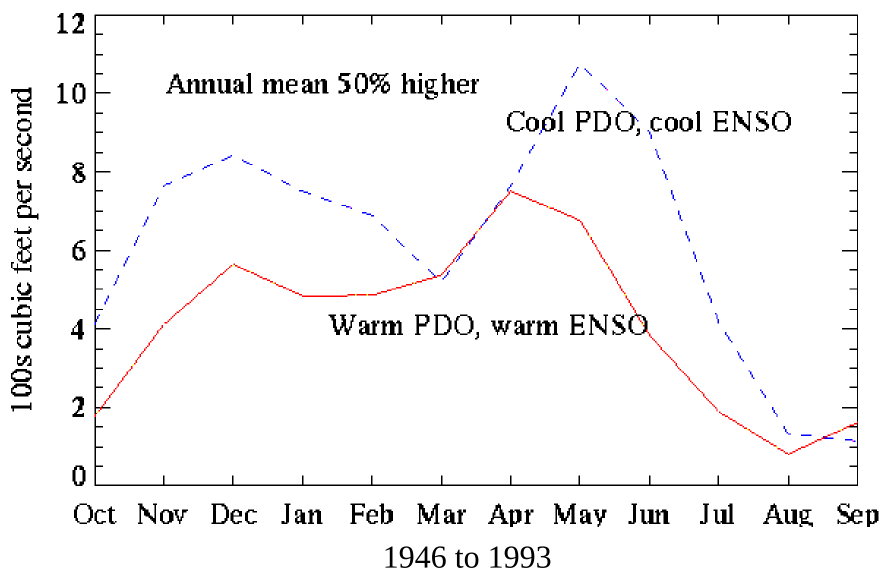

Figure 3. Chester Morse inflow.

Well, let's turn our vision toward the future here and talk about the science of global climate change. Some of you probably keep up with this issue quite a bit and others perhaps not as much, so let me just review some of the basic scientific facts that are known. The scientific basis for climate change rests really on very simple physical principles, and that is that greenhouse gasses like carbon dioxide keep the earth warm. We know that; it's no mystery that without greenhouse gasses, earth would be a frozen ball, and we wouldn't be sitting in this lecture room. But we do have greenhouse gasses—carbon dioxide and water vapor for example.

Over thousands of years, if we look back at records left in ice cores, temperature and carbon dioxide have tended to vary in sync and there are good physical reasons for that. Now the next important fact is that greenhouse gasses, for example carbon dioxide, are increasing because of human activities, primarily but not exclusively fossil fuel use. Carbon dioxide, for example, has increased by about a third since the beginning of the industrial revolution; half of that increase, in fact, was just since 1970. Just in our lifetimes. So that's a pretty big force.

What do we see going into the future? There are a couple of important questions to know the answer to before we look into the future. First of all, has climate already changed because of human activities? There has been a warming of about one degree Fahrenheit over the last 100 years, and scientists have pretty much come to the conclusion now that half of that warming or a good deal of that warming is because of human activities.

The next question is, how much will earth's average temperature warm up over the next 100 years? In order to answer these question…in 1988 the United Nations Environment Program and the World Meteorological Organization put together the Intergovernmental Panel on Climate Change, which was given the monumental task of summarizing all of the peer-reviewed research on the issue of climate change and coming up with both a substantial document and with a summary for policy makers. The most recent summary for policy makers was released last month and said there is stronger evidence yet that humans have caused a warming of climate in the last 50 years.

Part of that evidence rests on this diagram (Figure 4), which was published in Geophysical Research Letters two years ago. It's a reconstruction of northern hemisphere average temperatures going back to AD 1000 from tree rings and other proxy data. You can faintly see the error bars on the proxy data going back, and of course they increase as you go back in time. The blue curve here is the individual years and then the black is a smooth curve, and a few features come readily to mind. First of all, from AD 1000 to 1900, there was a very slight cooling of a couple tenths of a degree Fahrenheit in the northern hemisphere average. There were also some cool and warm interludes but none of these compares in magnitude or rapidity with the warming we've seen since humans began changing the composition of the atmosphere. You can see a very sharp warming from 1900 to 1940, a period of slight cooling and then an even stronger period of warming since about 1970, which remember, was the time when we reached about half the magnitude of CO_2 increase.

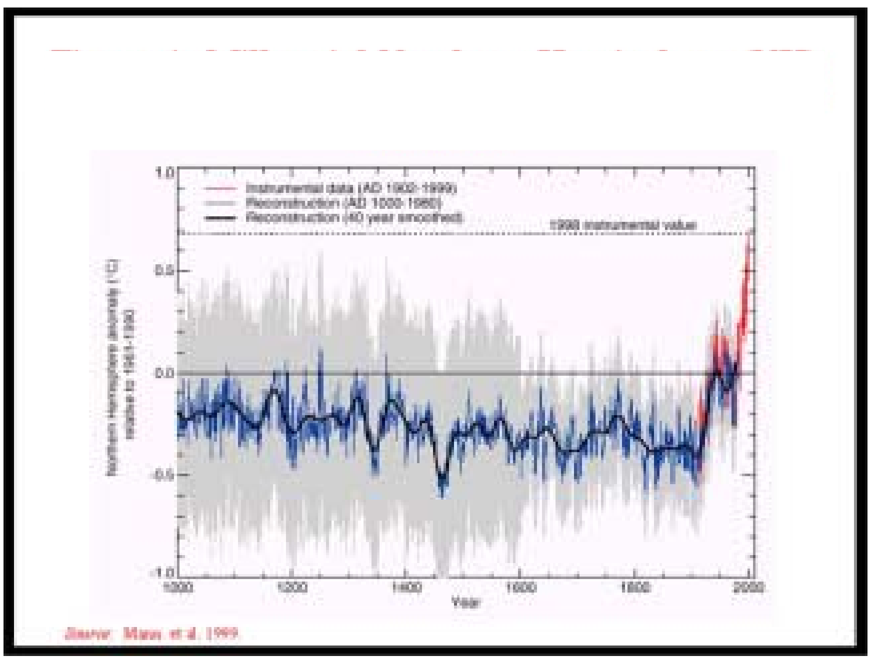

Figure 4. The earth is warming—abruptly. Millennial Northern Hemisphere (NH). Temperature reconstruction (blue) and instrumental data (red) from AD 1000-1999.

The 1998 instrumental value was far and away the warmest year in the last thousand. And this provides fairly convincing evidence that what is happening to our climate is unnatural. So going out into the future, the IPCC used socioeconomic scenarios to imagine what would happen to CO_2 and they came up with this scenario for climate change in the next one hundred years, a warming of roughly 1.5° C, 3° F as the lowest bound of likely warming. And an upper bound of more than 10°F.

Now these bounds really depend on what happens in our socioeconomic development. Do we continue to have rapid globalization and reliance on fossil fuels that gets us on this top curve, or does the world become more isolated, slower growth and perhaps a turning toward renewable energy? So in the sort of best case scenario, the planet only warms up 3° F, which remember, is about three times what we saw in the last 100 years.

What would that mean for the Northwest? We've already seen a warming of about 1.5° F over the last 100 years and the warmest decade was the 1990s, although the warmest year was back in the 1930s. We can go back even farther in the Climate Impacts Group. One of the scientists—a masters student—has looked at geoducks, of all things, which live for a 150 or more years, and they lay down annual growth rings just like trees. I was rather astounded to learn this—that something so homely could provide such useful information. Nonetheless, there are a whole bunch of geoduck samples collected around Puget Sound and the most useful ones seem to come from Protection Island and this (Figure 5) shows a reconstruction from four of those time series going back to 1835. And it seems to suggest that, as the instrumental record tells us, the 1990s were the warmest decade. The 1930s were also pretty warm, and this preliminary analysis seems to suggest that a period from about 1855 to 1870 was also unusually warm. There is the possibility of checking this against tree rings and we are working on that.

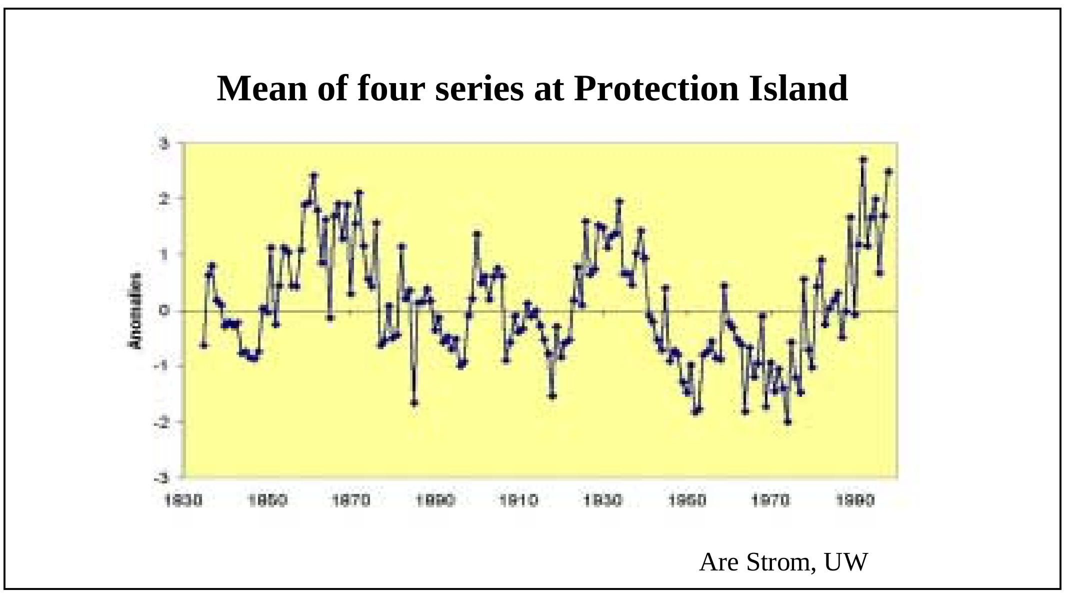

Figure 5. Geoduck growth 1835 to 1998.

But going into the future, we need to be able to simulate climate—and this (Figure 6) is a simulation of global climate from the Canadian Climate Model up in Victoria, and we've extracted the patch of earth that corresponds to the Pacific Northwest—and when this model is forced with the observed carbon dioxide increases, the trend over 100 years is almost exactly as observed.

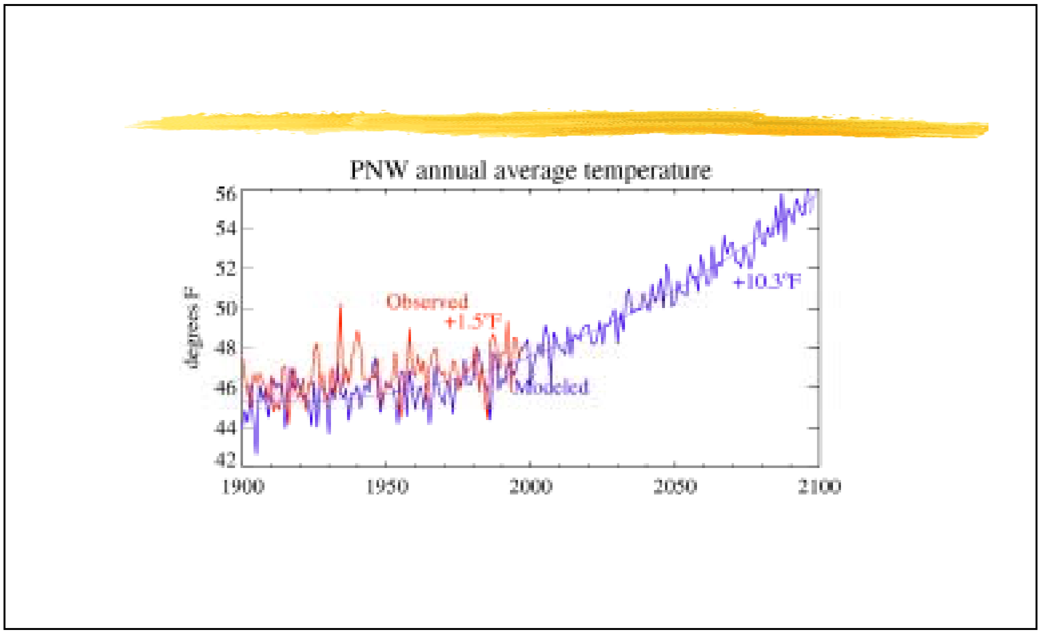

Figure 6. Modeled temperature to 2100.

We don't expect individual years to match up because the model has internal variability, but this is a fairly striking confirmation that some of the warming we've seen in the Northwest is probably caused by carbon dioxide. Going out into the future, this model gives us a fairly frightening view of what the future climate could be like: a 10° warming from 1900 to 2100 and of course we've only seen a little bit of that. Now none of us are going to be alive in 2100, so lets look at the more near term future, say the 2020s, and you notice that the cool years in the 2020s are what we would consider very warm years for even the 20th Century. So this is what I mean by pulling the rug out, that the average conditions will be changing rapidly.

We've actually looked at eight different climate models to get scenarios of future climates (Figure 7). This one in blue shows the one that I just showed; these are 10-year averages, with the observed record in light blue and you can see the 1990s are about a degree warmer than any other decade in the Northwest in the last 100 years. And then these are the two extreme scenarios of these eight climate scenarios.

If you want to be an optimist, focus on the green curve where by the 2020s we've only warmed up another roughly degree and a half. You can be an optimist if you want, probably the more realistic projection is what the average of the models says and that's for a warming rate of about two thirds of a degree per decade going out to the 2040s and, in fact, beyond.

And then, if you want to be a pessimist, look at this red scenario where it warms up substantially by the 2040s. What about precipitation? Climate models do a much better job at temperature than precipitation, so our projections are not as confident. But all eight of these models say winter precipitation increases, so it's not quite right to think of this winter as a paradigm. We're about 40 percent below average precipitation this winter, very unusual. The average of these models say a 9% increase, and they are sort of divided about whether summers will be wetter or drier, but the actual amounts of rain are very small because it doesn't rain much here in the summer. The main impact of these changes would be a substantial reduction in snow pack. As a rough rule of thumb, if it warms up 1°F, that's equivalent to raising the snow line about 300 feet. And so if you warm up say 4 or 5° F, that's 1200 to 1500 feet, and that substantially reduces the area of the mountains that are covered with snow.

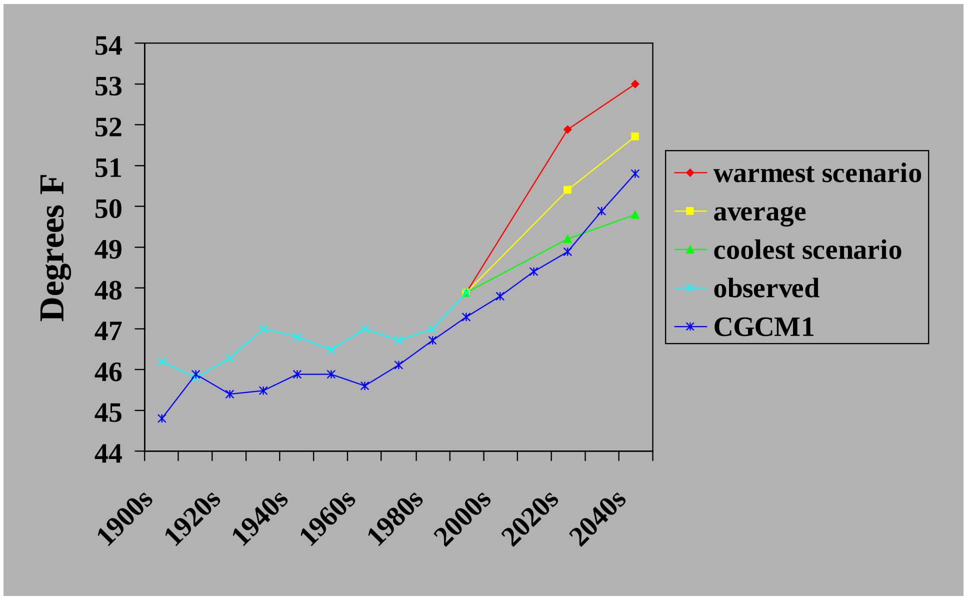

Figure 7. Northwest warming scenarios.

And that is shown here. This is a hydrology model for the Columbia River Basin. That's why it doesn't show any thing outside the basin, but the red blotch—excuse the coloring—is meant to be snow and you see that as we warm up to the 2020s, a substantial area of the lower elevation basin looses its snow pack. For salmon, we know that climate influences the quality of stream, estuarine and ocean habitat. And we know from studies, from our own studies, that salmon abundance is highly correlated with PDO warm phase mean low abundance. And we expect that the sorts of climate changes that we see higher temperature, increased flood frequencies would be bad for salmon.

For forests, vegetation modeling done at Oregon State (Figure 8) suggests an overall greening of the Northwest, but if you look very carefully the areas in brown (decreasing vegetation) are where most of the forests grow. That would clearly have an influence on ecosystems as well through the ability to regulate stream flow and provide habitat. Coasts—there is a talk this afternoon in Session 2C by a couple of our colleagues including one on coasts, so I urge you to go there if you want more details—but as sea level rises, we expect a number of stresses on ecosystems and human infrastructure as well. Olympia, because south Puget Sound is sinking fairly fast already, is perhaps the most vulnerable. Also landslides, if you remember a few years ago. Heavy winter rainfall tends to mean more landslides, so don't buy a home in Magnolia if you can help it.

Are we prepared for a change in climate? What if managers are trying to hold some resource on a certain path and climate is pushing it in another direction? For example, suppose you're trying to keep Douglas fir on a patch and it wants to go over to ponderosa pine? That gets more and more expensive as time goes on, and as we well know, sometimes nature wins and you end up back at the natural state anyway. And then you've lost all that investment.

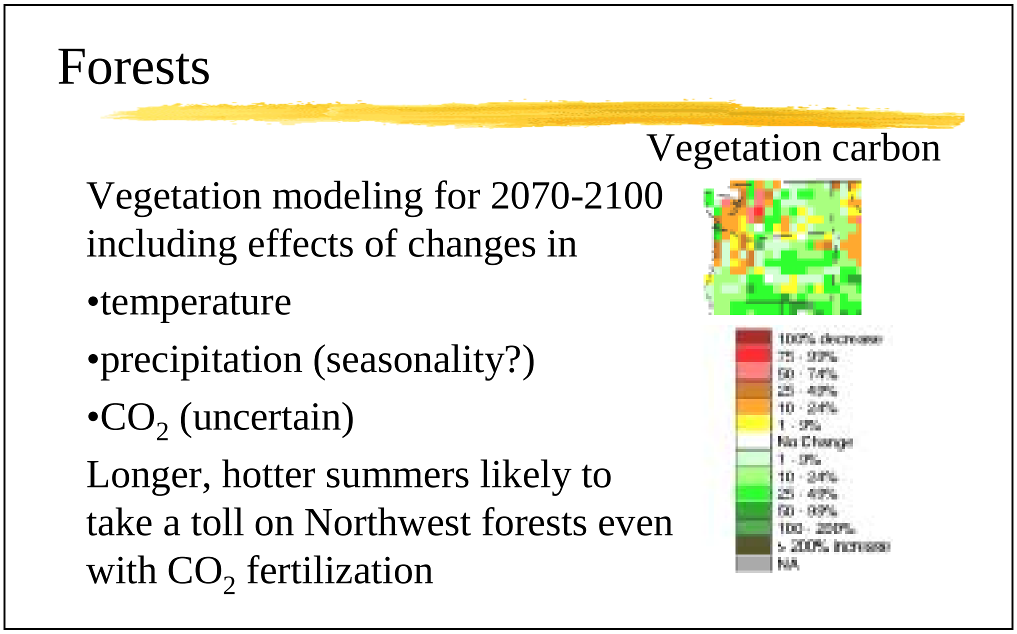

Figure 8. Effects of climate change on Pacific Northwest forests.

In conclusion, climate change is likely to significantly affect the Pacific Northwest. In the 21st century, the consensus of global climate scientists is that it's going to warm up at least a few degrees on the global average. It's something we cannot ignore. The main impact for our region is likely to be the reduction in snow pack, and what that will do to summer stream flow. That portends big changes for sensitive species and ecosystems. There may be a lot of exotic species that move in as it warms up, and some species that have narrow tolerance for temperature fluctuations might be pushed out. Any long-range plan of natural resources clearly should consider the possibility of climate change because prudent planning requires considering all possible scenarios for the future. And the consensus of climate scientists is that a warming is not just possible but very likely.

Recent Increases in Coho Production in the Strait of Georgia are Related to Changes in Climate

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Pacific Biological Station, Fisheries and Oceans Canada

Abstract
There was a major increase in early marine survival of coho and other Pacific salmon species in 2000. The increased survival of coho was associated with increased size and fitness. There also was a major increase in euphausiid biomass and individual size. These changes indicate that productivity increased in 2000 in the Strait of Georgia relative to 1997, 1998 and 1999. The changes are consistent with a regime shift in 1998 around the North Pacific that may be as significant as the 1977 regime shift. A synchrony among the productivity shift of coho, a change in regimes, and a new state in the rotational velocity of the solid Earth (LOD) is an indication that the dynamics of coho production can change abruptly from regional climate related processes that have associations with planetary events.

Introduction
Climate and climate change have not been included in the traditional list of factors that alter the abundance trends of the Pacific salmon species that originate in the rivers around the Georgia Basin. The traditional view has been that fishing rates were so high and freshwater habitat problems so prevalent that the bottleneck to rebuilding salmon stocks was the number of juveniles that entered the ocean. Obviously this number is important, but our studies show that not only is climate very important, but that the impact of climate can be abrupt and impressive.

We have been studying the early marine period of Pacific salmon in the Strait of Georgia since 1997. We started earlier than this, but it was not until 1997 that we settled on a standard fishing and sampling program. In this paper we show only the results of a portion of this study.

Methods
The survey design is shown in Figure 1. It takes between 8 to 10 days to complete a survey depending on the facility with which fishing and sampling occurs and the generosity of the officials that control ships budgets. The key to our study is the ability to catch all sizes of salmon, at any depth, during virtually any kind of weather. We use a modified trawl net that can be towed at approximately 5 miles/hr (Beamish and others 2000a). The net opening has been modified so that it does not catch too many salmon. We also keep the tow length to 30 min to reduce catches. The net has an opening of approximately 30m by 15m when fishing and "filters" 2.08 x 10^6 m^3 during a standard tow. Abundance estimates are swept volume estimate that assumes that all salmon in front of the opening are captured. This "catchability" of 1 most likely is too high, resulting in an underestimate of abundance. There are no calibration studies that can be used to estimate this error, but some Russian studies using larger nets and larger vessels have shown that the catchability of trawls could be less than 0.5. If this estimate

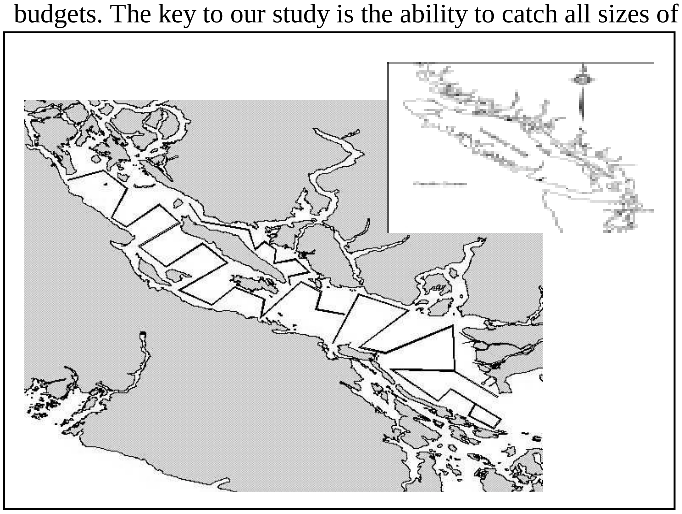

Figure 1. Location of the Strait of Georgia showing the standard survey lines.

were used in our study, it would mean that the abundance estimates were low by about 50%. However, we believe that the abundance estimates are relative among years and are valuable measures of population dynamics in the same way that the catches in standardized research surveys are a common tool in stock assessment (Doubleday and Rivard 1981). Other details of the survey design and sampling have been described in Beamish and others (2000a).

Results and Discussion

The dates of the various cruises, the total number of tows in the Strait of Georgia, and the total catches of all ocean age 0 Pacific salmon are shown in Table 1. The estimated abundances for ocean age 0 coho, chinook, and chum are shown in Figure 2 for the July and September surveys from 1997 to 2000. In 2000 there was a substantial increase in July in the abundance of coho, and smaller increases for other species of juvenile salmon. We refer to this period as the early marine period, thus the increased survival represents increased early marine survival.

Table 1. Survey dates, the total number of tows for each survey, the number of tows in the Strait of Georgia and the resulting catch of all ocean age 0 Pacific salmon of all species in the Strait of Georgia. The results from the surveys used in this report are highlighted.

	Date	Total number of tows	Number of sets in Strait of Georgia	Total Catch of all age 0 salmon in the Strait of Georgia
1996	Sept 09-20	82	62	7536
	Nov 04-15	82	57	1883
1997	Feb 20 – Mar 03	52	39	27
	Apr 07 – May 02	181	70	75
	May 26 – Jun 07	86	48	2920
	Jun 17 – Jul 11	**186**	**68**	**4383**
	Sept 08-27	**141**	**128**	**11062**
	Oct 17 – Nov 01	95	58	3193
1998	Feb 09 – Mar 07	130	44	8
	Apr 06-25	124	43	1
	Jun 22 – Jul 15	**157**	**92**	**10178**
	Sept 08-26	**160**	**95**	**9314**
	Nov 16-30	117	95	1743
1999	Feb 12 – Mar 08	53	53	50
	Jun 29 – Jul 19	**186**	**98**	**7714**
	Aug 04-08	47	0	0
	Aug 31- Sept 19	**172**	**85**	**6527**
	Oct 18-23	35	13	913
2000	Mar 29-31	16	9	0
	Jun 26 – Jul 24	**205**	**82**	**25208**
	Sept 05 – Oct 03	**226**	**81**	**7856**
	Nov 01-10	99	18	1149
2001	Mar 25 – Apr 01	55	25	2
	Jun 29 – July 22	217	89	14691

In this paper, we describe only the results for coho. The abundances in July 2000 were 6.8, 4.6, and 3.3 times greater than in 1997, 1998, and 1999 respectively (Figure 2). In September 2000 we did not observe the same relative increase in coho abundance as we did in July 2000. In September 2000, there were 5.4 times the coded-wire tagged (CWT) coho captured per unit of effort outside of the Strait of Georgia than in any of the previous three years (72 tows, 4 CWTs from Canada in 1999; 87 tows, 26 CWTs from Canada in 2000). This indicates that in 2000, juvenile coho were leaving the Strait of Georgia earlier than in the previous three years. We propose that the change in behaviour is related to the improved growth, the greater abundance of coho, and possibly the greater densities of chum and pink salmon juveniles.

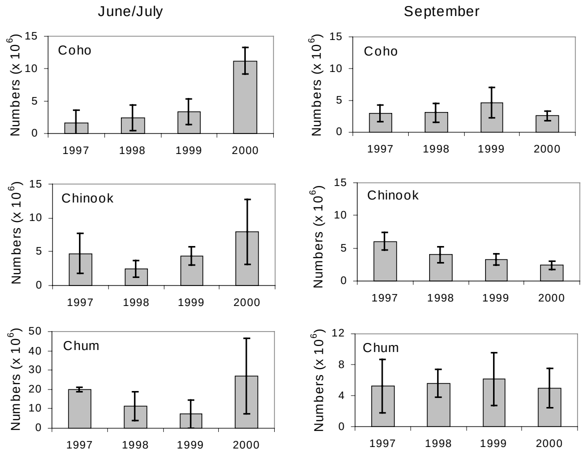

Figure 2. Abundance of ocean age 0 coho, chinook, and chum in the 8 surveys. Vertical bar represents plus and mjnus two standard deviations of the mean.

In addition to the larger abundance in July 2000, coho were larger in size and had a larger condition factor (Figure 3). The comparisons among years are influenced by sampling dates as well as feeding conditions, thus, a comparison of size could be influenced by the date of sampling. However, despite some differences in the date and duration of the sampling period, the mean lengths in the July samples in 1997, 1998, and 1999 were similar; (172 mm, 177mm, and 172 mm respectively; standard deviation (SD) of 23, 23 and 20 respectively). The mean length of 200 mm (SD 24) in 2000 represented a large and significant increase (t test, p < 0.01) in individual average length. In September 2000, the average length of 250mm (SD 23) was the largest of the 4 samples, but it was only marginally larger than the average size of 246 mm (SD 21) in 1997.

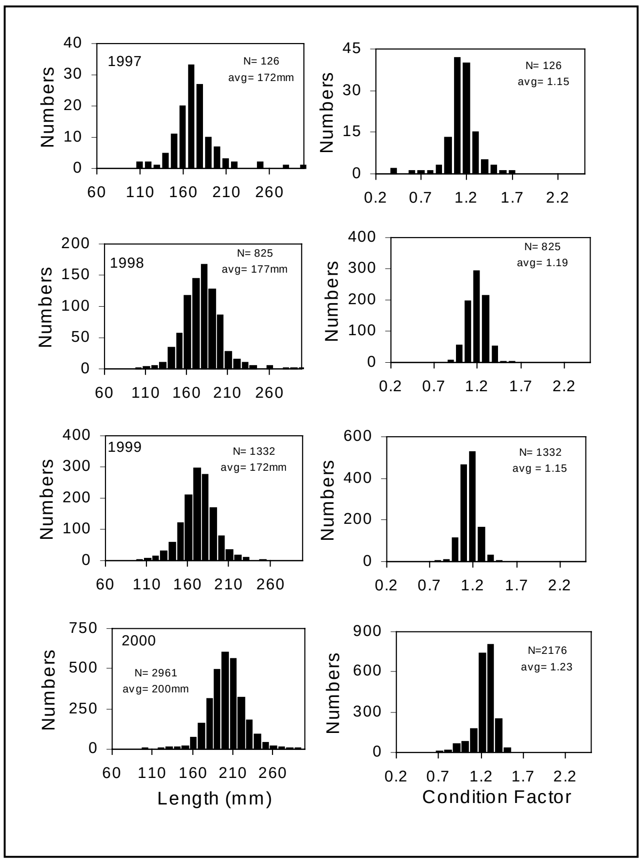

Figure 3. The length frequency and fitness ((weight/length3)x100) for coho sampled in the June/July surveys.

In all surveys we sampled the gut contents of coho and determined the species composition and prey volume. Species composition was determined by an experienced taxonomist using 10 x magnification when necessary. All contents were examined within 1 hour of capture, and most contents of coho guts were examined within 30 minutes of capture. The same person examined all contents, in all surveys, in all years. Using this approach, we were able to process large numbers of gut samples. We also were able to determine the identity of some prey such as "jellies" and "fish remains" that could not be determined from preserved samples. The total number of coho stomachs examined that contained prey items in the 8 surveys from 1997 to 2000 was 5,354. These represented 77.9% of all coho examined. The remaining coho had less than 0.1 cc (22.1%) and were considered to have empty guts. In all June /July surveys the items representing the major prey groups by volume were decapods (46%-68%), teleosts (21%-45%), amphipods (1%-10%), euphausiids (1%-6%), and other/unknown (0%-1%) (Figure 4). In all 4 surveys, these were the dominant prey groups, with the order of dominance virtually unchanged. In the September surveys (Figure 5), the dominant prey groups were unchanged although the order of dominance varied (Figure 5). Contents by volume were decapods (1-4%), teleosts (14%-34%), amphipods (11%-34%), euphausiids (21%-60%) and other/unknown (2%-7%). Two observations were noteworthy in the September samples. First, fish remains (teleost), which were mostly young-of-the-year Pacific herring, were a common food item but never the dominant food item. Second, the percentage of euphausiids in the guts in the June/July samples was very low and in September 2000 was less than in the previous years. The reduced percentage of euphausiids was surprising because we observed that in 2000, the biomass of euphausiids doubled compared to the biomass in 2001. Not only did the biomass of euphausiids double, but individual size increased (Figure 7). The increase in size and abundance of euphausiids indicates that there must have been a substantial increase in the biomass of the food of euphausiids. Because the dominant species in the plankton is *Euphausia pacifica*, and it feeds primarily on phytoplankton (Siegel and Nicol 2000), there must have been a major increase in primary production in 2000 compared to the previous three years.

We have a balanced Ecopath model for the Strait of Georgia for 1998 that contains 32 functional groups (Table 2) (Beamish and Neville 2001, Beamish and others 2001). In 1998, the percentage of the total production of euphausiids that was consumed by prey or transported out of the system (ecotrophic efficiency) was 75.5%. When the 2000 biomass of euphausiids is used in a new model (2001) without other changes, this percentage drops to 37.8%. It is clear that in 2000, there was a large abundance of euphausiids that was available for consumption by traditional predators, but euphausiids do not increase in volume in coho diets.

The increased abundance, size, and fitness of coho in July 2000 is an indication that the earliest marine survival was greater than in the previous three years. The increased individual size was an indication that more food was available. We propose that the improved survival was a result of reduced predation-based mortality. We have shown in a previous study (Beamish and others 2001, Beamish and others 1992) that spiny dogfish (*Squalus acanthius*) are a major predator of salmon smolts when smolts first enter the Strait of Georgia. Spiny dogfish also feed on euphausiids, and we propose that the increased abundance of euphausiids may have provided alternate, and even preferred alternate prey, reducing predation on coho.

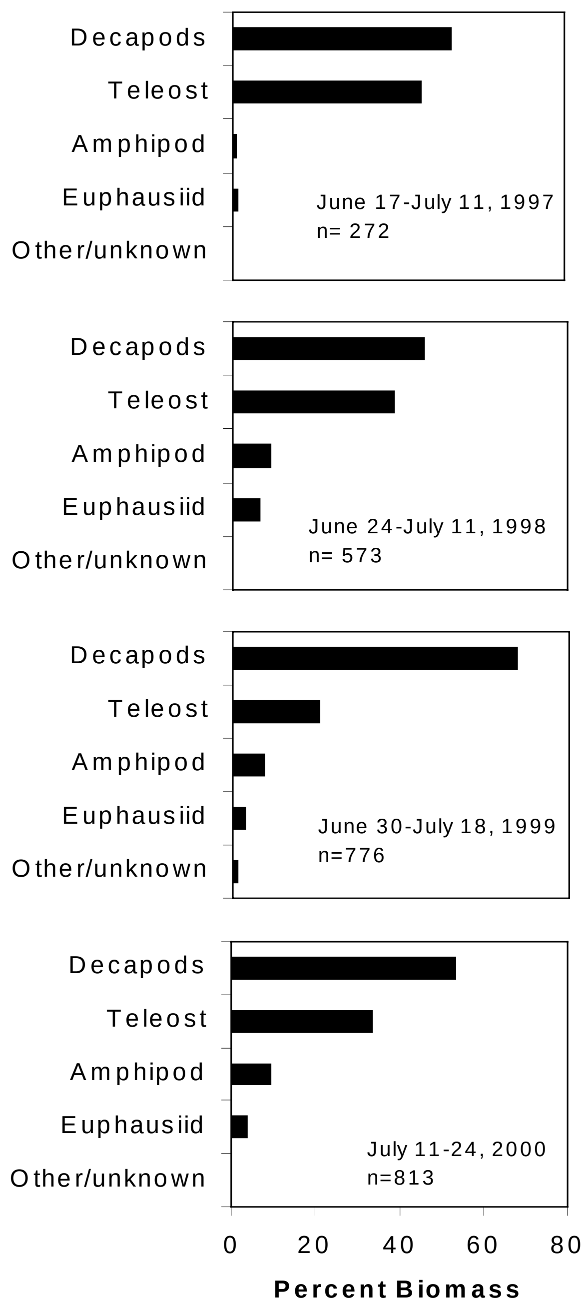

Figure 4. The percent biomass of gut contents of ocean age 0 coho salmon collected from the Strait of Georgia in July 1997 to 2000.

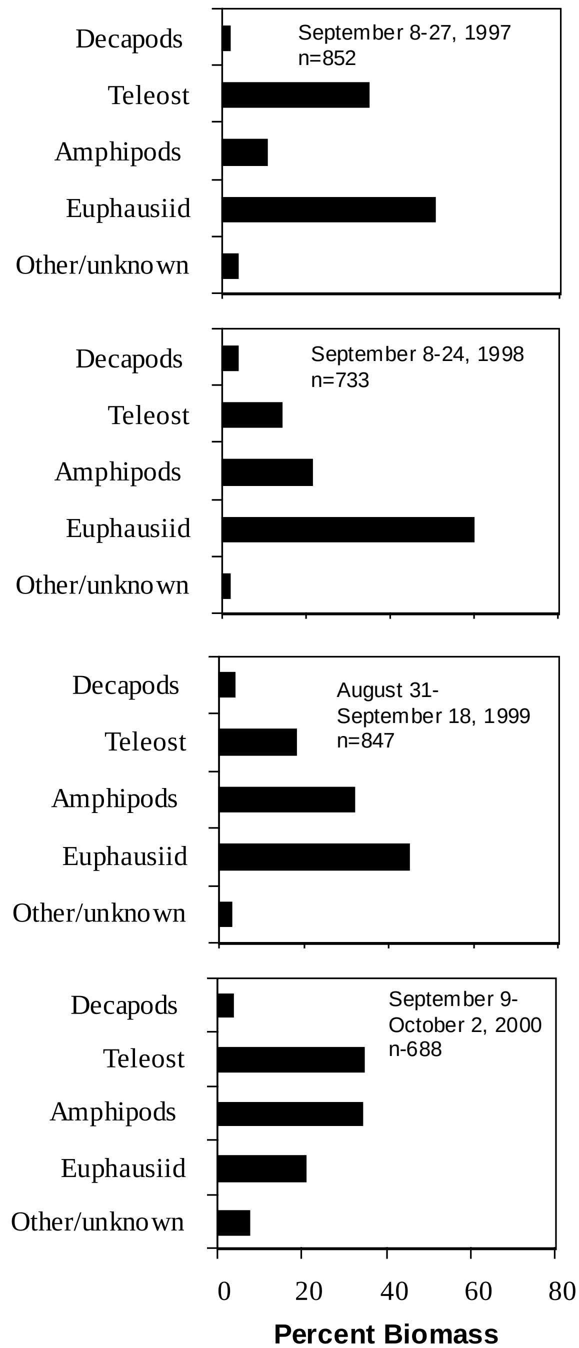

Figure 5. The percent biomass of gut contents of ocean age 0 coho salmon collected from the Strait of Georgia in September 1997 to 2000.

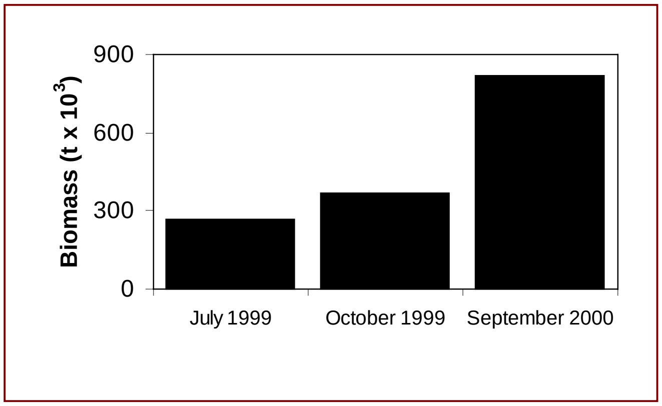

Figure 6. The biomass of euphausiids in the Strait of Georgia, determined from hydroacoustic surveys.

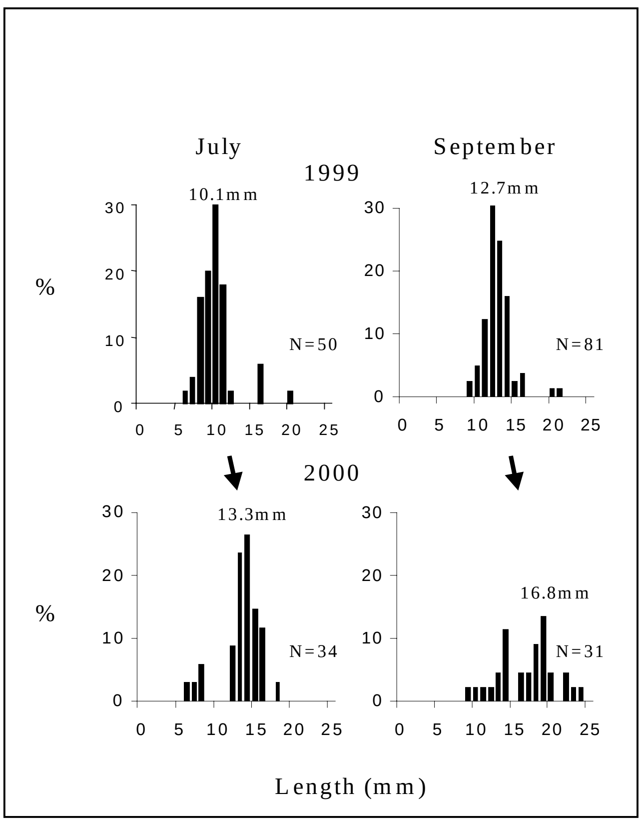

Figure 7. The lengths of euphausiids sampled from the Strait of Georgia in 1999 and 2000.

Table 2. Functional groups, biomass, production/biomass and consumption/biomass values listed in the Strait of Georgia ecopath model and resulting ecotrophic efficiencies.

Functional Group	Biomass (t/km2) 1998	Biomass (t/km2) 2001	Production/Biomass (t/year)	Consumption/Biomass (t/year)	Ecotrophic Efficiency 1998	Ecotrophic Efficiency 2001
Phytoplankton	36.000	72.000	130.000		0.992	0.912
Kelp/Sea Grass	23.300	23.300	34.000		0.280	0.559
Herbiverous zooplankton	25.000	50.000	20.000	80.000	0.892	0.647
Neocalanus plumchrus	25.000	40.000	20.000	80.000	0.909	0.796
Pseudocalanus minutus	10.000	20.000	20.000	80.000	0.878	0.668
Shellfish	60.000	90.000	3.000	12.000	0.569	0.636
Crab	4.000	8.000	3.500	14.000	0.671	0.461
Grazing Invertebrates	40.000	90.000	3.000	12.000	0.729	0.493
Carniverous Zooplankton	40.000	50.000	5.000	20.000	0.581	0.912
Euphausiid	80.000	160.000	3.000	12.000	0.755	0.581
Predatory Invertebrate	25.000	25.000	5.000	20.000	0.293	0.488
Shorebirds	0.005	0.005	0.100	5.000	0.000	0.000
Herring	9.000	13.000	3.000	12.000	0.787	0.886
Small Pelagics	15.000	40.000	2.000	8.000	0.770	0.704
Lampetra ayresi	0.020	0.020	2.000	8.000	0.782	0.782
Seabirds	0.018	0.018	0.100	5.000	0.009	0.009
Gulls	0.004	0.004	0.100	12.500	0.000	0.000
Misc. demersal fish	20.000	50.000	2.100	8.400	0.431	0.412
Chum	1.000	2.000	2.000	8.000	0.398	0.364
Coho	1.000	2.000	3.000	12.000	0.361	0.357
Chinook	1.000	2.000	2.000	8.000	0.445	0.421
Toothed Whales	0.003	0.003	0.020	0.400	0.000	0.000
Hake	10.000	14.000	0.600	2.400	0.559	0.783
Dogfish	4.500	4.500	0.100	1.000	0.052	0.052
Lingcod	0.350	0.350	0.500	2.000	0.114	0.114
Pollock	2.000	2.000	0.600	2.400	0.124	0.206
Leuroglossus	0.200	0.400	2.000	8.000	0.660	0.342
Yelloweye	0.500	0.500	0.200	2.000	0.070	0.070
English Sole	1.000	1.000	0.180	0.720	0.034	0.034
Sea Lions	0.020	0.020	0.180	21.600	0.013	0.013
Seals	0.050	0.050	0.125	15.510	0.028	0.028
Detritus	38.700	38.700			0.572	0.529

Table 3. The total number of juvenile coho entering the Strait of Georgia in 1997, 1998, 1999, and 2000. All estimates are from Sweeting et al (2001). Hatchery releases from Canada include a calculated estimate of hatchery released fry survival to the smolt stage.

Year	Releases from Canadian hatcheries ($x10^6$)	Hatchery and wild juveniles from U.S. ($X 10^6$)	Percentage of hatchery coho in Sepember	Total number of coho ($x 10^6$)
1997	9.0	0.99	67.9%	14.7
1998	9.7	1.07	71.9%	14.98
1999	9.9	1.09	79.3%	13.86
2000	10.0	1.10	69.3%	16.02

The dramatic improvement in production of plankton and coho in 2000 was associated with a dramatic change in climate. In 1998 there was a rapid change from El Niño conditions to a La Niña state (McPhaden 1999). There also was a large-scale shift in climate and ocean conditions that appears to be persistent. Various authors have proposed that this persistence indicates a new regime started in 1998 (Beamish and others1998; Beamish and others 2000b; McFarlane and others 2000). Many people now are familiar with the concept of regime shifts. It's a concept that still remains to be proven, but evidence is accumulating that indicates there are these persistent states that switch from one state to another. We speculate that the change in 1998 caused the productivity changes in the Strait of Georgia in 2000 and is probably as significant as the changes that occurred after 1977 (Beamish and others 2000b). There is the evidence that links the regional changes we saw in the Strait of Georgia with planetary events. Recently, Beamish and others (2000b) have proposed that an index of regime change could be the change in Earth rotational velocity or the length of day. The length of day (LOD) is the deviation from the standard length of day which is the time required for the solid earth (crust and mantle) to complete one rotation (Beamish and others 1999). A persistent change in the trend in the length of day represents a major change in the energy distribution among the atmosphere, hydrosphere, the solid Earth, and the liquid core. The four shells of our planet do not complete a rotation in the same length of time. The atmosphere, the hydrosphere or the ocean, the solid earth, and the liquid core all turn at slightly different velocities. Changes in the length of day represents an energy transfer among these various spheres. The seasonal length of day (Figure 8) slows in the winter, because energy has to come from somewhere for the increased winter winds in the Northern Hemisphere. As the winds weaken in the summer, there is a speeding up of the solid Earth. In Figure 8, it is clear that there was a shift in the seasonal pattern of the solid Earth in May of 1998 and that this shift represents a new state. Beginning in May of 1998, the solid Earth has been spinning faster and this trend persists. The increase in productivity in the Strait of Georgia and the resulting effects on coho populations, therefore, can be related to marine habitat changes that are both regional and planetary.

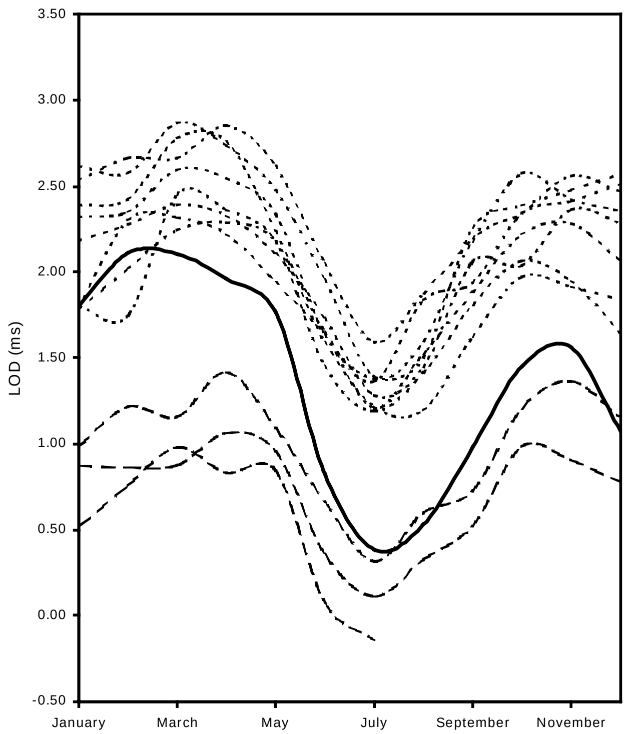

Figure 8. Length of Day (LOD) values from International Earth Rotation Service (IERS), Paris, France. Each curve represents the average monthly length of day for the years 1990-1997 (dotted lines), 1998 (solid line) and 1999 to mid-2001 (dashed lines). Note the change in the trend in May 1998.

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Puget Sound in a Broader Context: Global Threats to Marine Biodiversity

Dr. Elliott Norse
Marine Conservation Biology Institute

In real life in the 1960s and 70s, I was a blue crab biologist. And I focused; I really focused on blue crabs. They were very big in my life, for a decade. Then in the 1980s, I found myself working on forests, although I'm trained as a marine ecologist, and again for about 5 years these trees, and these forestry ecosystems were very, very big in my life. And the message here is that we become involved and enmeshed in the work we do, and it's very easy to hold onto the piece that we have. But what I'm really interested in discussing with you is the relationship between the piece each of us has and the larger context. And I think we'll do a lot of good, if we keep that larger context in mind as we do all of the important things that we do.

(View of a photo from outer space.) This is as large a context as I feel comfortable with. The affairs of the western spiral arm of the galaxy are beyond me, but this isn't…and this is a daily concern…and if you take a look at that picture, the tritest thing you'll ever hear, and yet it bears repeating *ad nauseam*, is that most of what you see is marine. Marine realm occupies 71 percent of the area, but by volume, if you don't include organisms in the lithosphere, we're probably talking about more than 99 percent of the volume of the biosphere is marine. So actually all of you terrestrial and freshwater people who thought you were doing something important, you're not. It's just an afterthought.

Well I'm only kidding. Some of my best friends are terrestrial. Now I got lucky. Okay I was someone once. I worked for President Carter for about a year and a half at the Council on Environmental Quality and I was a marine ecologist and really what I was, was a blue crab ecologist, and I didn't know the larger picture until I got an assignment. And the assignment from my boss who worked for the president was to write a chapter on the status of life on earth for our annual report in 1980. And it became clear to me that he wanted me to look at the status of life at different levels of hierarchical organization. And so we called it "biological diversity."

By biological diversity what we mean is, the level that most people think about and have thought about of and some people still think about and that is the middle-level species diversity, but there is a lower level, more fundamental level, genetic diversity within a species. I illustrate it with tomatoes and that's because I have tomato envy. And if what Phil says is correct, maybe my envy will be fulfilled before I die because, you see it's funny you know you come to the Puget Sound region and you see all of these great recipes for green tomato relish, green tomato chutney and things like that and there is a message in that, and maybe, maybe as the climate in the Puget Sound Basin becomes that of Portland and then becomes that of Medford and then becomes that of Indio or whatever, we will ultimately be able to grow tomatoes.

Now the important point here is that the genetic diversity within the tomato genome is the source of artificial selection for traits we care about. The genetic diversity within the genome of wild species is the raw material for evolution and evolution is what is going to be happening rapidly as the world changes, as it's changing very rapidly as well. Finally, the highest level is ecosystem diversity, and this is something we don't think about enough. If you look at the structure and species composition and functioning of this ecosystem, it's very different from this ecosystem.

So the point here is that I took this lesson into the return of my marine phase. I had a marine phase when I was in graduate school and my first couple of jobs, and then I had a forest phase, and now I'm back in the marine phase, mirroring in a fairly precise but nonetheless intriguing way the Pacific Decadal Oscillation. And in pulling together this book, what I've found is that there are five proximate threats and there are five ultimate threats to marine biodiversity and biodiversity in general and I want to share them with you. And if you ask the reason, why are there five rather than four or 73? Hold your hand in front of your face and count your fingers. It's a memorable number. And they are: over-exploitation of species; physical alteration of ecosystems; pollution of the medium—in this case the sea; introduction of alien species; and finally, global atmospheric change. And this was an important realization because in 1989 when I got the assignment to start pulling together my marine biodiversity book, what we were being told was that there were two threats to the ocean: overfishing and pollution. And the truth is much more complex and interesting than that.

So overfishing is one that a lot of people had focused on, although they focused on it in a very narrow way. They look…there is a paradigm that looks at fish populations one by one in isolation from all other populations. It doesn't look at lower trophic levels or higher trophic levels or other species at the same trophic level, and looking at fish in a black box has gotten us into some trouble, which is why we have, in many cases, the overfishing problems that we do. Because the world is more complex than that. But also we catch other species when we fish, and we have physical effects in the ecosystems when we fish. We alter food webs as a result of doing a variety of things when we fish, that is one issue.

A second issue is physical alteration. This is what the west coast of North America used to look like. This is what more and more of the west coast of North America looks like now, and I'm not saying this is bad. When I need my urban fix I gird myself and go across the bridge, 520, and go into Seattle and get it, but there are consequences to these choices we make. Substantial consequences. The chickens are coming home to roost in a big way.

This plant in Port Angeles is closed now, but pollution is a serious issue. This was the ITT Rayonier Paper Mill. Pollution was a substantial issue before the passage of the Clean Water Act. It still is, you know this, it is more so in semi-enclosed basins such as Puget Sound. The area of Puget Sound is much, much bigger than it appears, the blue part of it appears to be on the map. Because things that people do in a wide area of our region winds up draining into the sound. I don't have to tell you this, you know it, but the concept that Puget Sound is nested in a large ecosystem is an important one if we want to maintain biological diversity with in our region.

Here is a fourth threat. Now this may look like a log ship to you. In Aberdeen I took this on a Light Hawk flight, some years ago, and you may not think that this is a threat to the marine realm, but when those log ships go heavily laden across the Pacific and they come back, they come back not with cargo, but laden with sea water. Their ballast tanks are full. And when they discharge their ballast tanks in Puget Sound and other places they are discharging 10 million, 20 million and 50 million gallon aquaria containing the sea water from Pusan Harbor or Tokyo Bay or other places, and some of the organisms from those places are finding a commodious place to live. Now the next organism here—green crab is an example of an invader. It didn't invade by ballast water; it probably invaded in another pathway, perhaps by FedEx, in a shipment of clam worms from Maine, that somebody got here and went out and fished with. But the important point is that what's happening far away profoundly affects our region.

Finally, there is global atmospheric change, and we've had such good input from the first two presentations. You realize that we are intimately tied with the temperature regime and hence the precipitation regime and hence the snow regime and the upwelling regime and all of the other things that effect biological diversity within Puget Sound and our broader region. Not surprisingly, the iconic species of our region are showing the effects of what we are doing. This one, this one, but these are only the tip of the iceberg, because although we spend inordinately large amounts of our effort looking at those species, other species that get almost no effort, or no effort (in some cases they are not even yet identified by scientists) are also being subjected to the same forcing and are very likely showing comparable changes in their patterns of abundance and their dynamics. And this is an issue of great importance to us.

Now I'd like us to come face to face with some serious questions here and serious concerns. One is that the proximate causes of biodiversity loss are being driven by five ultimate causes: there are too many of us; we consume too much—gosh, I was stuck in a line of five sport utility vehicles on my way driving here—and I wish I had my camera. I could have included that here.

Our institutions degrade rather than conserve biological diversity. That’s a big one for me. We don’t have the knowledge we need and we don’t value nature enough. Now the institution question is really important because we have just undergone another regime shift and the regime shift is an important one, and it places incredible emphasis on what we do here in Washington. If we are going to protect our environment, we cannot necessarily look to other places including this one for a great deal of help. And that’s one part of the equation. The other part of the equation is that if Washington and Oregon and Vermont and New York and New Jersey and a couple of other states that have been improving their environmental quality records are silent, then the only voices that will be heard will be ones that have a very different way of looking at things. One thing that I’m really concerned about right now is that the essential fish habitat provisions of the Magnuson-Stevens Act are going to be assailed in this coming Congress—the new Congress. And I worry about this a lot because whether you care about salmon in Puget Sound or rockfish 50 miles off the coast of Washington, these essential fish habitat provisions are vitally important. And I’m afraid that in this current regime we’re going to be seeing them come under a major threat and people here in this room can make a difference.

We should look at Puget Sound in a broader context. Here’s a broader context, it’s not the entire world ocean, which is a little bit hard to put on a single piece of paper. But what I’d like to show you here is those dark areas are U.S. waters. The total area of waters under U.S. jurisdiction is about 4.4 million square miles. It’s larger than the area of the United State land mass, including Alaska and Hawaii, etc. The important point here is that we’ve got a lot of underwater real estate under our control. And this past year President Clinton signed an executive order 13158 establishing or towards establishing a national system of marine protected areas in the United States. I think marine protected areas, in particular marine reserves, areas that we protect from all kinds of harm whether they be…all kinds of preventable harm…we can’t protect against global climate change, whether it be overfishing, of pollution or whatever, physical alteration, is very important. We can zone areas of the sea for different uses, including full protection. And doing so is an area of enormous research interest.

Again, I think looking at the whole context is the way to go and people are an instrumental part of that context, and if we do it we’re going to have what we love about this region to the maximum extent possible. Again, I’m reminded, Phil, of your slide showing the increasing management cost of trying to keep an ecosystem the way it was, as increasing forcing is pushing it. But this is what we came here for, and I’d like to give you a little, an invitation. I’d like to open this possibility, we started Marine Conservation Biology Institute in Redmond in 1996. It’s the only national conservation organization headquartered in the Pacific Northwest, and MCBI has put together the first symposium on marine conservation biology in Victoria in 1997. We’re doing it again this time in San Francisco. It will bring together people who work on all aspects of biodiversity research: who look at all the threats; who look at the different hierarchical levels; and what we hope to do is look at some of the hottest questions. And the interesting thing is in the abstracts on the contributed papers I've gotten so far, half of the abstracts concern marine protected areas. So I’m beginning to understand what my fellow scientists think is really hot. I hope you’ll be there in San Francisco and I want to say thank you for coming to this conference.

Plenary Panel Discussion

Nancy McKay:
I want to thank all three of the speakers for very interesting and provocative conversations with us.

I ask all of you to work with us for the remainder of the session. We're trying a sort of experiment here to get some of your questions answered, and also as I've pointed out, when I introduced our first three presenters, to begin a conversation among the scientists and the people whom I'm about to introduce.

On my far right is **John Dodge,** who is a senior reporter for the *Olympian* and has covered environmental, natural resources and energy issues since 1984. He is author of a number of award-winning special reports on issues such as Pacific Northwest salmon, water quality in Puget Sound, the health of our forests and geologic hazards on Mt. Rainier. John is currently working on the fifth installment in a yearlong look at the effects of population growth, and development on the quality of life in south Puget Sound. Earlier installments of that series earned him the 2000 Dolly Connelly award for excellence in environmental journalism. Mr. Dodge is a native of Washington having lived as he told me, most of his life a stone's throw from Puget Sound.

Next to John, is **Kirk Anderson,** Kirk is employed by Fisher Companies Inc. in Seattle and his present role with the company involves him in business development, especially in the areas of media and communications. He is a Washington native also. He holds a bachelors degree in business administration and worked as property manager for the commercial real estate firm, Cushman and Wakefield, until he joined Fisher real estate division in 1983 in a similar capacity. A year later he was promoted to director of operations and to vice president of Fisher Properties in 1991. In 1999 Mr. Anderson accepted an offer to transition from the real estate division into his present role. He has served on many industry committees, task forces and panels both locally and nationally. He is a member of the Puget Sound Council, which advises the Action Team, and represents businesses on the council.

Next to me is **Dr. Jacques White**, who is the habitat program director for People for Puget Sound and is responsible for coordinating the activities of that organization's habitat team. He holds a Ph.D. in marine estuarine and environmental sciences from the University of Maryland. Dr. White has held research positions at the Smithsonian Environmental Research Center and the University of Delaware, he has taught at the University of Maryland and he has done marine research on all three coasts of the United States.

Now what I'd like to do is address a couple of questions, I think first to our scientists and then begin to turn the conversation to our other three panelists.

And so I want to start out with a question for Dr. Beamish: **How much longer can we expect higher abundance of coho, chinook and chum? And I'm told that you need to be about a foot from the microphone.**

Beamish: Is how much longer in days, hours, or years? The answer would be that I certainly wouldn't know. But that's not what I'm sure the person was expecting. What I was trying to show was that in addition to the stewardship which we have to show, which is a combination of realistic expectations both in the ocean and in fresh water, that there are these natural forces that have rather spectacular effects on the marine survival of salmon. Global warming is a serious concern, and I thought that that was a very excellent presentation, so I'm not sure that we know the true impacts of global warming are going to be in terms of the ecosystem. It's my opinion that it is probably the most serious threat to salmon in this area because I think that we do have the ability to correct some of the freshwater problems. So if I had to say, give a time frame I would say that coho are going to be around for sometime.

McKay: Good, thank you. For Dr. Mote—How will climate change affect ENSO and PDO and will these changes in combination overwhelm salmon recovery efforts?

Mote: Climate models are still struggling to represent current ENSO like and PDO variability. Some of them are getting much better at it and that of course is a prerequisite for believing what they say about future changes. Most climate models tend to have more El Niño events in the future as the ocean warms up, but some simply settle into a less variable future, so it's a little early to say about that part. How will these changes together overwhelm salmon recovery efforts? Well over the near term we have shifted into a cool phase of the PDO as some of the biological indicators as well as the physical conditions. It could be that that would sort of mask some of the global warming for awhile, and if we get a regime shift toward greater…toward warmer conditions in, say 20 years. This is very speculative, possibility because we really don't understand how the PDO works, but if that were the case then we could see a sort of abrupt warming as some of this concealed warming was unmasked. And those changes, salmon of course, you know we can influence their freshwater habitat but not their ocean habitat. And I think Dr. Beamish would agree with me, we still have a long way to go to understanding how climate influences salmon in their ocean habitat. We have some clues about their fresh water habitat, certainly the best chance we can give them is to improve freshwater habitat. I don't think as one questioner asked that we should write them off because global warming is going to wipe them all out any way. There are a few salmon species that still thrive down in California. Biodiversity, I think, is the answer for giving salmon the best shot along with habitat.

McKay: Thank you. Question for Dr. Norse. And I'm not going to ask him to answer this, but we got one that said:
Could you please explain the Magnuson-Stevens Act? And if you would like to give us a little on that that would be wonderful.

Norse: Sure. Named in part for our own Senator Warren Magnuson, who was a great Washington political leader and Senator Ted Stevens of Alaska. This act, originally passed in the 1970s and reauthorized in the 1990s, contains a number of provisions regarding fisheries in U.S. waters. Its goals are basically to prevent over fishing, to reduce by catch of species that we are not trying to fish, and to protect the habitat of fish species. Now the habitat of fish species is, are freshwater in the case of anadromous fish, and estuarine and marine ecosystems. And so the Magnuson-Stevens Act now says: Thou shalt not destroy essential fish habitat. There are some folks who think that we've gone too far in saying we shouldn't destroy the homes of fish and that provides too much of a legal means of protecting the environment. And that is not a good thing, and that is a large concern for those of us who've been working for many, many years to get the idea that fish are wildlife, too.

Nancy McKay: Thank you very much. Kirk, from your perspective as the representative of the business community on the Puget Sound Council: What do you think are the most critical issues that should be addressed by the region's natural resource scientists? And, if you want to, what request would you make of the entire audience that is here today?

Anderson: That's a very difficult question for a layman like me to answer, because I feel a bit intimidated by all of you out here who are far more informed on this subject than am I. In my role on the council however in just working out in the community, I guess the things that I would suggest or say are funding is probably the biggest challenge that occurs to me. And one of the things that I think precipitates funding is communication. Your ability—our collective ability—to communicate the body of work that you all are doing. And get that to the man and woman on the street so that in a way that they can understand it. And I think that if that happens I think that we find a lot of passionate people who are out there who would love very much to get behind and find ways to save our salmon, save the environment, bring biodiversity back, all of those other things that we are talking about here today. I don't think that I'm alone as a representative in the business community who feels that these issues are fundamentally important to our sustained ability to have a growing and robust economy. And so that's what I would offer up.

Nancy McKay: Thank you. John, you based your recent series of articles on interviews with a whole bunch of people: scientists, planners, activists, farmers, land owners, and a shell fish grower. From what you heard during those interviews and your own analysis of the issue what do you think are the primary challenges that are facing us in the Puget Sound and Georgia Basin as a community as we grapple with growth and environmental protection? And what should scientists in the region be doing to help us address those issues?

Dodge: Okay, I do this with a little bit of reluctance, but I think it will help tell the point. How many of you folks out there are native Washingtonians? That is a lot better than most of the roomfuls of people that I ask that question to. What I've learned in the last 15 years of reporting on Puget Sound health leaves me skeptical at best about our ability to sustain and improve water quality and marine ecosystems and still have the projected levels of growth that we see staring us in the face. I see the altered shorelines and the nonpoint pollution and the direct wastewater discharges, continued growth of impervious surface are all running counter to our efforts to restore and protect Puget Sound. We've had a Growth Management Act for 10 years now. I'm sure that we are better off today than we would have been if we had stayed on the same path and didn't have that act, and we're working to better manage our growth. So don't get me wrong, I don't think that the efforts to manage growth are in vain, but I suggest that they are probably not enough if we are truly serious about restoring and protecting Puget Sound biodiversity and water quality, ecosystems into the future.

So what do we do? Well. I think first and foremost we need to enforce the laws…the environmental and land use laws that are on the books. Too often the law, the land use regulations, they look good on the books, but they just don't get practiced just out on the ground. There are too many waivers, too much looking the other way, too much development activity that just does not lend itself to Puget Sound health. I think that if Puget Sound restoration is to be a priority it has to continue to resonate with the public who in turn must elect county commissioners, city council members, state legislatures, who make it a priority. It was an issue, back in 1984-1985, when the Puget Sound Water Quality Authority (Action Team) came into being and we had issues that were very visible and emotional. We were watching the concern with the gray whale deaths and the mortality rates of gray whales, and we were seeing shellfish beds closing all up and down Puget Sound, and it was easy to get attention, and we got attention. And we set this institution in place and it has moved forward, but I'd venture to guess today probably on your mind more or on the mind of the public are things like the energy shortage or energy crisis. And so how does Puget Sound compete with that? Well, that's where the scientists can play a very important role; the scientists need to continue to connect the dots.

We hear a lot about primal causes and primal effects and somehow we need to keep making the connections between all of these things, we have to explain about and understand better: Why are we seeing these toxic algae blooms spreading both in frequency and in spacial distribution? The roll that the overall biodiversity does play in the salmon, in the decline in the salmon runs, disruptions in the marine food chain. I know there is a lot of good work going on out there; it's important that the scientists continue to speak with candor and speak with passion and don't be afraid to tell us the consequences of our action or our inaction. So often good science is overridden by the politics of the day, and I don't have to look very far for a good example. Look what's happening with the attempt to beef up our state shoreline regulations, based on good science struggling politically. So I guess maybe not very encouraging words, but I think they are practical. So I hope you keep up the good work. But you face an up hill battle because there's just too darn many of us.

Nancy McKay: Thank you John. I think. Thank you. Jacques, from you position as a leading scientist and advocate for the Puget Sound region:
What are the two or three most critical questions that you think scientists should address to ensure the restoration and sustainability of the shared waters of Puget Sound and the Georgia Basin?

White: Well, I don't know if I can tell you what the three most important ones are. I think that the slide that Elliott showed during his talk kind of outline what the challenges are facing marine waters in general but pretty much facing the Sound as well. These five, basically five, at least five different major insults.

I'm going to confess to being tipped off that I might see a question like this, so I have been thinking about it and thought about some specific things but another one of the questions that was addressed to us as we were thinking about this was: What should scientists do to ensure their work is incorporated in multitude of plans, projects, programs that protect and restore the regions environment? And on thinking about that I thought maybe you should run for elected office. Because your ability to influence those decisions after you've done your best that you can in research is somewhat limited if you want to maintain your level of effectiveness? But I know several people who have scientific backgrounds that have gone into elected office and are currently being quite effective in influencing public policy, first because they have a basic set of background of logical thinking and problem solving and secondly because they have some innate understanding or the ability to, in the training to understand complicated questions. I would argue that if any of you are feeling frustrated and limited in the scope of your ability to change things you should think about public life.

On the three questions, I think that I picked sort of two and a half of the topics that Elliott mentioned. One would be pollution, the other would be habitat loss, and the third is overfishing or how we might manage that here. In the first case, I think that there is emerging research that indicates toxic materials are getting into the food web in Puget Sound and that there is some concern that that may be having an impact of the health of the ecosystem. So I would encourage people who have the ability to do so, to study the sub-lethal effects of contaminated materials as they enter the food chain and as they propagate up through the food chain and what effect those might be having on the species that we care about.

I went to some of my colleagues in the office, and I said, "What do you think is the most important scientific question?" And I went in one door and somebody said, "We know what the problems are, just go fix them. We don't need to do any more studies." And so I said, "Well, this is a scientific meeting and they are going to want to hear about science." And so I went to the next door and I basically got the answer and so I stopped going into the offices. And I have to qualify that all my answers here are predicated on the fact that we are going to go forward assuming the precautionary rule and not do bad things as we advocate to our managers.

But there are some issues that we need to address. And in the context of the sub-lethal issues a specific question might be: "How clean is clean enough if we're doing contaminated sediment remediation?" And then following that we might ask specific questions that can help managers make decisions.

In the context of habitat loss, how many people have heard nearshore spoke in the same sentence as salmon in the last year? Good. I think that it is very important that we begin in earnest to study the ecological processes on our nearshore environment including from the subtidal up to the nearshore upland areas in order to gain a better qualitative and quantitative understanding of how those processes affect the health of the ecosystem, the nearshore ecosystem, and in how that functions to support the rest of the Puget Sound ecosystem. And one of the questions that we might ask in particular is: "Where do salmon go when they leave a river in Puget Sound? And what do they do there?"

On the nearshore, we're pretty sure that when you tow a net that you're going to find salmon there. Another question that is sort of related to that might be more policy driven is: "How much shoreline estuarine restoration is necessary to support a sustainable ecosystem? How much do we have to repair if we're in a net debt right now? What level of restoration do we have to achieve in order to make sure that the ecosystem that we have is sustainable?"

And the last major question I think we need information on is to collect fine scale enough hydrographic, bathymetric and biological data that is necessary so that we can develop a systematic program for conservation of marine areas of Puget Sound. An example of that might be: how is marine fish larva distribution and settlement affected by currents and bathymetry in the Sound? So we can get an idea of where we would place conservation areas and a management question related to that would be: "How do we build a decision tool or some kind of GIS or spatial decision tool or model that will allow stakeholders to build an effective system of marine protected areas that all interested parties in the region can live with?" So I haven't answered, I think there are many more important questions that we need to ask, but those are three that I've been thinking about lately.

Nancy McKay: Thank you very much. I'd like to ask a question to anyone who wants to jump in. **Q: How should scientists connect the dots? And Elliott, you talked about the need to improve institutions. Jacques is talking about how do you do something that is spatial and still requires political decision making. I'm sort of trying to tie all of those things together into a question to any of you, about what's the best way to bring us all together so we can move forward? And in particular are there ways in which scientists could be working better together? Anybody want to take that? I'm sure it's an easy answer.**

Norse: I became fascinated some years ago by something called a Meyers-Briggs personality type indicator. Meyer-Briggs looks at personality type and how it effects people in their love lives, their educational lives, their business lives, etc. One of the things I found, interestingly enough, is that most scientists are introverted. Interesting thought. Now what is an introvert? It's a person who tends to do best alone or in intimate groups of people, people he or she trusts, and knows well. And introverts usually tend to want to go more deeply into things rather than having lots and lots of superficial relationships. What Jacques said before, we should run for public office, I thought to myself, my God I'd make a lousy politician because I want to spend my time with my best friends, reading, and doing things that introverts do. So one of the problems I think we have a scientists is that its harder for us as an oppressed minority because introverts make up about a quarter of the population to work with the large majority of Americans who are extroverted and who wonder why we want to spend so much time with our books.

Anderson: I'll just I'll add a couple of things to that, because I think that there is a definite language barrier between the language of any discipline and the language of the common person. I found that in coming onto the Puget Sound Council, I thought I was reasonably intelligent until after the first meeting and then I had serious doubts. But it takes a while to learn your language, and I think what you're all really trying to do in your research is your trying to find ways to solve significant problems both socially and environmentally. And your work is tremendously important.

As a member of the Puget Sound Council, I find it profoundly important on the council is being around the table with a group of people from a wide variety and diversity of background and interests. And it's difficult at times to bring competing interests to the table because you've got to learn new languages. You've got to learn new ways of relating, new ways of talking. But I think, really, that the payoff for that is that we can really begin to move together as a community and I know from my experience in trying to pull people in the business community into this conversation, which is, I'll admit to you it's not an easy task. However there are people that are significantly interested and genuinely interested. And what they need is what you have, and so I guess one way to maybe begin to approach that is cooperate amongst yourselves, try to do a lot more joint work and sharing of your information and be thinking about how can I take this to your son or your daughter or a relative that's not in your discipline and communicate it with them so that they can understand what it is that you are so excited about.

Dodge: One other idea—each year the Action Team puts out the *Puget Sound's Health* report, and that in itself is a good first step in bridging from the science to the layperson. I've often though how could it even be better? Because what happens for me is I read it, and it's always a mixed bag. It's mixed signals: some things are getting better; some things are getting worse, so you go to your editor and you say well, their first question is well, "What's the deal? Is Puget Sound getting healthier or sicker?" And you go, "Well, it's a little bit of this and it's a little bit of that, and pretty soon you're in the gray; it's not black or white, it's all shade of gray. I accept that and understand that from the complexity of the issue, but if there was some way of weighing or weighting the various indices that are used to make the measurement and then kind of come up with an overall trend so that we could be more definitive about whether we're making progress or not or if the areas where we're making progress outweighs the ones where we're slipping and measure it in a, I don't know if scientists would be willing to do that, but it's an idea.

Beamish: So the question was, "How could scientists connect the dots?" Or something like that. You know I think one of the most impressive things I've seen in the time I've been in this business, is this meeting. I can't believe how many people are here, and obviously you're concerned about your quality of life and the environment. Science isn't science until it is communicated to others, and that's what this meeting is doing, so to be honest with you and to be very frank, I wouldn't be worried about it with the interest that I've seen here.

Anderson: Just one other thing, one other anecdotal piece of information to share with you on this subject. I've got two kids, a 14-year-old daughter and an 11-year-old son, and they've been involved in elementary school education programs in the Bear Creek Watershed, and I can tell you that there are programs like that around these communities that go wanting for and looking for qualified people who are knowledgeable in that arena to be able to come in help relate to these kids the things that you all know. It's been a profound success in my view, my kids are tremendously aware of the environment and are growing up to be environmental stewards, and that's not really so much to do with anything I've done. I really characterize that result as a product of the education they've received through this awareness program in teaching them through the watershed. So little things like that can have a tremendous impact, especially when you consider that all of these kids that have been through that program, the thousands of them are going out and they are going to sitting in our chairs years from now.

White: I think that question is more important than it maybe sounds on the surface. One of the things that I've been thinking about pretty much ever since coming here is, how do you people talk about ecosystem management as a tool or an approach that we should be thinking about, because essentially the world is like one huge, very complicated version of the game "Mouse Trap" where something happens and then something else happens, and you have this chain reaction, and the event that finally occurs may not have been predicted by looking at the first event.

My fundamental understanding of this came as at one point in my life I was a bio-geochemist working on marine bacteria, and in a search for meaningfulness at cocktail parties, I used to try to explain to people what that meant in the larger context. And I started to take an ecosystem perspective just out of necessity so people wouldn't walk away from me after 40 seconds. I think that is the struggle that we face.

I came to this job with that perspective, and after a short time of reviewing the way at least our natural resource agencies are set up, basically through legislative mandates, that are now quite old, most of you in this room who practice that art are set up for failure, and it's unfortunate, and I'm sorry for you. But we really need to think about how we can get around the structural impediments to thinking about Puget Sound as one system, work together one of the tools that I think is being developed regionally that offers some promise in getting us down the road to seeing Puget Sound as one system is the PRISM model that is being developed at the University of Washington. I hold out great hope that that, or some effort like that, will help us to start to view Puget Sound as one system. We can see that the shoreline is connected to the marine waters, that the watersheds are connected to the shoreline, and that what we do someplace has remote, but distinct, impacts. And I think as we start to think about that and develop tools for us to think in the larger perspective, I don't want people to lose site of the important work that you're doing on a particular species or managing a particular resource, but we need to think about were those are connected and so I would urge everybody as you're here to keep an open mind and start thinking about how, what you do or what you study is influenced by, or influences the person next to you.

Nancy McKay: Great answers. I'm going to switch the question a little bit, to ask you just to follow on and ask you, a comment that John Dodge made, to the rest of you each of you is working on specific issues, Elliot you gave us a list of five things that we should pay attention to because we can count them on our hand, so we can remember them and I guess the question that I have for all of you is:

Q: Can we do what John (Dodge) was talking about? Can we weigh indicators in such a way that we can tell a different story when we talk about Puget Sound in terms of what's most important to be dealing with, what's second most important to be dealing with, what's third most important to be dealing with, and I guess what I'm talking about here is, my observation that that's the way to political process works. You want money, Kirk (Anderson), you raised the issue of funding. Tell me what the most critical need is because we only have enough money to fund one critical need. How important is the second need, so sort of with that background is there anyone that wants to, I'm really interested in what, especially some of the scientists would say. How should we go about that?

Or should we do it. Are there dangers, in doing that especially when we're also trying to get people to think in large systems? And pull things together.

White: I'll take a stab at it. I would say that the important thing that I think about when I'm trying to suggest to people that they should put their energy some place is what is the permanence of the disturbance. It there is some disturbance out there that people are causing? Is it relatively…is it permanent or is it reversible? And I tend to address or feel that people should address permanent disturbances first, in the context of setting a priority, and so if I was a scientist trying to identify what the problems are, and I was trying to evaluate those that would be the criteria I would use.

McKay: Anybody else? Kirk (Anderson)**?**

Anderson: Just a comment on the funding question. I think that there are two ways to look at funding. There's what we have available today, constrained by a budget. And then there's what's truly out there and available if we have the will. And I have to keep harping on this, but I'll come back to the communication issue again. I think that all of us can think about issues, issues that are issues today, for example Mothers Against Drunk Driving. Probably none of us give that much of a second thought today because it is so ingrained into our culture, and it's a part of something that's important to all of us. But there was a time when that didn't exist, and I think that when we look at the funding issue, we can sometimes feel constrained and get into the hot sweats and the hand wringing and everything over how we are going to prioritize the issues and how were going to spend the limited resources we have. I guess I stand that the resource we have available, as a community are far broader than the current tax revenues that the state has available to spend. And it is really a choice that we have to make on what are our priorities.

McKay: Thank you, does anybody else want to take a stab at how you set those priorities? We've got a lot of questions here that we collected from all of you that ask the question about global warming, in one way or another. If climate change and global warming are going to make such huge changes in our ecosystem and our environment, then shouldn't that become the number one priority that we should be looking at, and does it overwhelm every other priority that we might be working on? And perhaps some of you who addressed the issue would like to talk about it for a moment.

Mote: To come back to John (Dodge)'s point about coming up with a single indicator and whether that would be useful in a warming world, there are a number of, my first reaction is I wouldn't want to try to do that because it just seems so daunting to rank the different problems. I appreciated what Jacques said about the permanence. I suppose another way to come at that would be the value to policymakers and there's such a bottleneck from the input of science to policy makers that anything that would improve that I think should at least be tried. In my field I mentioned the Intergovernmental Panel on Climate Change which has been trying to summarize what policymakers need to know about climate change and looking at how the IPCC report is covered in the newspapers. It's given roughly the same weight as an article in a third-rate journal that says that there's some evidence that climate change isn't occurring or some little wrinkle is really played up and the importance of the IPCC report gets lost. The value I think to policymakers, a congressman said to me once, he's like a TV set on which someone else is pressing the channel change button every 10 of 15 minutes. You spend your entire life focused on blue crabs or something and that's just sort of a blip on their screen. So to come up with a single indicator or maybe a set of five chief indicators of the overall health of Puget Sound and then boil it down to sort of a letter grade or something, I think would be useful. I'm not sure if it would, how may scientists would squirm to think of it, but you mentioned the issue of how do we factor global warming into all of this. Well clearly the past offers some clues about individual years that were warm and how the biota responded and the regime shift that Dick (Beamish) showed in the response of the marine life gives us some idea of the sensitivity. The problem that we often face in trying to quantify the relationships between physical and environment and the biota is one of monitoring and to have monitored something as thoroughly as they have twice a year for the last several years clearly is something that needs to be continued into the future. And as we develop a greater understanding of how species respond to temperature of freshwater input, differences then we can begin to make educated guesses about how they'll respond in the future, and how we can best manage and clearly from a broader policy context. It's also important to try to put the brakes on climate change. Are we going to settle for a doubling of carbon dioxide by the end of the century? That is actually an extremely ambitious goal to stop at a doubling of CO_2, most scientists think that a more realistic or a more likely goal would be two and a half times or three times. So the greater those changes the faster they come the harder it will be for species.

McKay: Thank you. John?

Dodge: There's a great irony here today to with what Phillip (Mote) is saying when you think about our recent response to the energy shortage. You know what are we doing, we're firing up dirty or fossil fuel plants than we were contemplating a year ago. Watch where our National Energy Policy heads in the next four to six years. Do you think its going to be climate-change friendly? I don't think so. So we know what the problem is, but are we willing to confront it? Are we willing to make the societal changes, behavioral changes, changes in our national energy policy that reflects the true urgency of the situation or do we just try to figure out some ways to get some more diesel generation and natural gas fired turbines on line?

Beamish: If you had to focus on one issue I would think that climate effects and climate change are our most serious issue for two reasons. One is that the impact that we might see in the Puget Sound or the Strait of Georgia are not necessarily from things that we did. We don't have a very good record of being able to negotiate environmental issues internationally. So the impacts that we cause and you all know that we are the major polluters per capita on the planet, okay, so the impacts that we cause affects other people's ecosystems. We see some of the impacts of climate on our own ecosystems and we understand very little about that. I participated in writing the third assessment report on for the IPCC which will come out in June and the shocking side of that was how little scientific literature is really available to those people who are trying to interpret climate impacts, so I…I am sounding maybe a little bit militant here, but to me it is the major issue… it's the pollution that we put into the atmosphere that's going to be our major threat, both to our own ecosystems and to other people.

McKay: That gets me to another question that was given to us by someone in the audience, which is:

Q: In light of the predicted rise in global temperature, change in climate, everything we've just been talking about—what should we do as we are developing conservation strategies? What kinds of policies, what kind of steps should we be taking? And clearly one of those I think we just had, which is we need…better ways to get the science out to decision makers and citizens. And we might want to talk about, specifically, what's the best way to do that? Are there new ways to do that? But there may be other ideas that you have about specific programs. We need to look at policies, we need to consider laws, that sort of thing. Or more research needs to be done clearly on these issues. Do you want to jump in there on that one? Where do we want to go with conservation strategies to address climate change? And global warming?

Mote: In the UW Climate Impacts Group, as I said, we're not just scientists, we really do try to make our science relevant and to answer one questioner's question that's why I used degrees Fahrenheit. I know a lot of nonscientists sometimes see our presentations, but we do use Celsius when we publish. The three steps that we sort of outline for regional adaptation to climate change are as follows: first of all, understand past climate variability and how it influences natural resources. Now, as I said, that's a real challenge for some of the biological variables, which we really don't know how they're responding to climate, but we're getting there with salmon. We're beginning to understand quantitatively how they respond. The second is to begin to incorporate short-term forecast, just the climate over the next year, into management decisions. We had some inkling already in November that this was going to be a low snow pack year, so how would that affect salmon habitat in the summer? That sort of step is a big one for natural resources managers to make because there's often a built-in assumption that every year is going to be average, and so to get away from that and look at how past years have varied, is quite important. And then the third, of course, is to say, "Well, if climate is warmer and these different things are more stressful or less stressful for certain ecosystems or components of ecosystems, how can we build management plans, scientifically sound management plans, that take into account these different possibilities or these changed components of their environment?" So there's three steps I think are important to adapting to a change in climate.

White: I'm not sure. I was a soldier in the climate change research army, at one point, I think it's tremendously important. But I question how much the people that are gathered here today can impact that through their research, and so I guess I have a couple of suggestions. The first is, how many people rode your bikes today? To this meeting? Boy. How many people rode the bus? Okay, tomorrow I hope more people raise their hands on both those issues. I mean I guess my point is that there are things, there are probably more that we can do personally to affect this issue than there is things that we can do through our scientific endeavor. There are thing we can do as citizens of democracies that may also have impact on this, but I think what I would suggest to people in the context of trying to identify some issues would be to think about how the research topic or the management issue that you are dealing with will be affected. And I think there are two important things that have to happen,. First of all, I'm going to harp on this, we have to start to have an ecosystem perspective and understand how the current Puget Sound system functions today—one degree warmer than it was 100 years ago, so that we have any chance of modeling how it's going to behave in the future and that may still be impossible. But I think that's really important . So I think you should think about how the system works as a whole. The second thing is, is how is it going to behave in the future? For example, we are endeavoring in this state to establish new shoreline guidelines on how we carry out the development on the marine shoreline. There are going to be both biological and political consequences of climate change on how that system functions,. First of all, I can't tell you exactly what the ecological consequences are, but it's not hard to see from a practical standpoint what the social consequences are going to be of a 1-meter rise in sea level if that were to occur. Telling people that they cannot armor their shoreline is going to become a difficult enterprise, so I think it's important that we start to try to put these pieces together, see what our future scenarios are, start planning, and maybe a stronger argument for things like maintaining less impervious surface in the watershed, moving people farther away from the shorelines because those are going to become increasingly unstable environments and difficult to protect their own private property, let alone resource that are there. So I think that as we are looking at a system that is going to be coming under stress, providing more resilience in the environment to support the existing resources is going to become a more and more compelling argument and compelling topic.

McKay: Thank you.

Norse: In contemplating the answers we've been giving and the question, I've gotten more and more uncomfortable with and the reason is that in my experience, I started in conservation in 1978, which is longer than some of you have been here. In my experience, bad things happen to things I care about. I'm being as simplistic as possible,. Almost inevitably because of multiple causative factors; it's what we call the old "double whammies" in the business. And the antidote to dealing with environmental problems is usually finding the one big thing. What's the answer? Is it climate change? Well, I'm thinking if we were to stop climate change cold if you'll forgive my pun, in its tracks right now, would we be in good shape? And the answer is, we'd be in awful shape. And that is true in the Puget Sound region and in our nation, and North America and going beyond. The problem we have is that we face human beings cause multiple changes in our environment and the changes work in different ways. In some cases synergistically to produce very rapid changes in the genes and populations and ecosystems that we're concerned about. And so I would hope that we don't look at…one good thing. If I had to boil it down to one good thing, one thing I've heard is that we need to communicate more with the public, which is a hard thing to do because we have probably not had good experiences communicating with the public in the past and we think they don't like us very much. But we need to keep doing it because in the absence of that we will have people speaking on our behalf who are like those that Phil (Mote) referred to who publish in the third rate journals somewhere and are given equal weight with the IPCC report. That's not a good thing. We know that one thing. Another thing is since we've all been asking you questions and asking you to wave your hands, I'm going to ask you a question, and I'd like you to wave your hands, How many of you contributed to political campaigns in this last election? Oh, not bad, about a quarter. That leaves about three quarters. I know that there are congress members in the Washington delegation that are really strong on climate change and other issues of direct relevance to what we've been talking about today. And there are others who represent the very, very opposite end of the continuum. With your energy, your intelligence, your dollars you can make a difference.

McKay: Thank you. Okay, I want to take the last five minutes, and first of all thank all of you who wrote down questions. We clearly didn't get to all of them, and I hope perhaps you can grab our speakers, perhaps right after this session and ask those questions or they may come up during the rest of the conference. But before we close, I'd like to ask each of you, very briefly, just to tell us if there is a question that you would really like to see us address as a group in the next two and a half days? What key question would you like to see this group of people really press on in the next two days together? And I won't go in order, anybody that wants to start. It doesn't have to be profound. It might be something having to do with scientific research.

Dodge: Well, being in the media communications business I would ask you, how can the media help? Part of the conversation that I'll share with you that we're having within our company is, how can we as a media communications company be more relevant to the communities that we serve? So I would offer myself. Nancy knows how to get hold of me. And so anyone after this session can find me as well. How can the media be of service to you in helping to get your message out?

Beamish: I think I agree. I think I could come up with some scientific questions, perhaps, but I do totally support the concept that the most important thing we can do is to communicate the science that we do both among ourselves and with the general public. A knowledgeable public is our best ally.

McKay: Does anybody what to second that? I see heads shaking, another question or challenge that you'd like to see the group work on. Discuss.

White: Being an organization (People for Puget Sound) that thrives on information and communicating it to the public, I appreciate this focus. I do have a question that is somewhat technical, that I think is pressing and of concern to me and I don't think we can answer it, but I hope that in the next two and a half days we can work towards framing the issue and the questions that need to be addressed on…There is a lot of money that is being proposed to be spent to restore habitat in the Puget Sound Basin. And I have some concerns that in the short run there are some no-brainier actions that we can all do, we'll feel good about them and they will be helpful. In the longer term, I think we are going to start reaching a point of diminishing returns or perhaps misspent or misdirected effort, and I would like to see us starting to thinking about, how do we develop a framework to prioritize restoration efforts across the entire basin? And I mean linking the marine waters, the marine shoreline, the estuaries, and the watershed. And we are way off of meeting that goal, and if you start adding up the dollars that are going to be spent, as we go to communicate to the public what we've accomplished with that effort it's going to be difficult to show that we have been thoughtful and made the best use of public resources. So I would like to see us thinking this is another part, as you can see, of my "It's the Ecosystem, Stupid" theme, but I think this would be very helpful.

McKay: Thank you. Anyone else?

Dodge: A couple things that are in my own backyard, in the South Sound area, that I'm actually going to go to the panel this afternoon, I think there is a presentation on what's being learned about nutrient loading in the South Sound, and I'm curious about what's happening with that. I also am interested in contaminated sediment cleanup issues. We've got a number of sites in Puget Sound and there are debates at almost every one of them about how clean is clean, and what's the best approach, should we excavate, should we cap, what should we be doing? Maybe it becomes a very site-specific set of answers, but I think those are a couple of important issues to keep exploring.

McKay: Thank you, I'd like to challenge each person in the audience just to think of your own question, of your own challenge. What would you like to find out about? What would you like to work on in the next 2-1/2 days while we are together? Try to make some headway on whatever that is. I'd like to thank everyone who participated in this panel. I think it's been very interesting. Wonderful presentations from our scientists and a good conversation, and I hope one of the points of it was to model what we hope will happen during the remainder of this conference. So I'd like to thank all of you for getting us off to a very good start. Thank you.